25 January 1961

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MEMORANDUM TO: [redacted]

FROM:

SUBJECT: Trip Report Los Angeles 15-20 January

FIRMS VISITED: [redacted] [redacted] 25X1A

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1. [redacted]

The object of this visit was to inspect progress in:

a. Image Correlator
b. Audio Film Equipment

A. Image Correlator

This contract is in good shape so far financially, but will require more time. Scheduled for March delivery, I estimate a further 45 days will be required. This delay has resulted from extended delivery time of certain optical parts which [redacted] required. The equipment has been fully designed and parts are now being assembled.

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[redacted] seem to have achieved excellent results in matching the eight objective focal lengths. These are now all well within acceptable limits of each other and what could be a major design difficulty is now accomplished. The attached budget sheet indicated the financial status which is good.

B. Audio Film

I was able to see the chassis with electronic components in an advanced state of assembly. Whilst this looked impressive, I was not able to see its capability demonstrated. However, I talked with the project engineer and I assume his complete confidence resulted from more than mere hope. Many trouble spots have been sorted out in the area of electronic balance and there is no reason to doubt the progress. Financially as the attached budget sheet shows, and ~~true~~ TIME-wise the contract is in good shape.

2. [redacted]

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TECHNICAL DEVELOPMENT AND SUPPORT STAFF ACTION SHEET



Date 27 Jan 61.

Originator: [redacted]

Subject or Identification of Covered Document:

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1. Concur
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(Original and 1 copy to accompany all documents forwarded to Ch/TISD)

# FINAL TECHNICAL REPORT

# MULTIPLE IMAGE CORRELATOR PROGRAM

Contract No. 25X1A

1 August 1962

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# LIST OF FIGURES

# MULTIPLE IMAGE CORRELATOR

Final Technical Report

## I. INTRODUCTION

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This is the final report for the [redacted] Multiple Image Correlator (MIC), an experimental equipment developed under [redacted] 25X1

Theory* and experiment demonstrate that grain-noise-limited photography can be enhanced by superposing light transmitted from "identical"** transparencies onto a very fine grain film. The MIC was designed to demonstrate that this technique could be implemented with precision equipment, and thus furnish the intelligence community with another important exploitation technique.

The experimental results obtained by the equipment have demonstrated conclusively that a dramatic improvement in the photographic information content can be obtained. In addition, it is clear that with refinements of design (i.e., certain desirable sophistications which were omitted due to a limited budget and the experimental nature of the equipment) a highly useful and versatile operational equipment can be built.

This report describes the technical approach, equipment configuration, and general operating procedures. Results are presented and recommendations for future work are made.

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* "Photographic Graininess Reduction by Superimposition" (Master of Arts Thesis, Boston U., Graduate School) Maj. B. W. Quinn, U.S.A.F., 1959

** "Identical" refers to separate photographs of a scene taken under identical conditions

## II. TECHNICAL APPROACH

In order to realize the maximum resolution of the optical system, the images should be aligned to each other within approximately one to two microns before superpositioning. Since such minute alignment tolerances may not be possible with the sole use of visual aligning techniques, an electronic system for detecting and minimizing alignment errors was developed. It was further concluded that alignment of several photographs and a subsequent composite photograph could be accomplished if the equipment were designed for two modes of operation: 1) a Projection Mode, for visual alignment of the transparencies, and for photographing the final composite result of the correlation process; and 2) a Scanning Mode, for electronic correlation and alignment of the images.

A functional block diagram of the equipment is given in Figure 1. A photograph of the [redacted] Multiple Image Correlator is shown in Figure 2.

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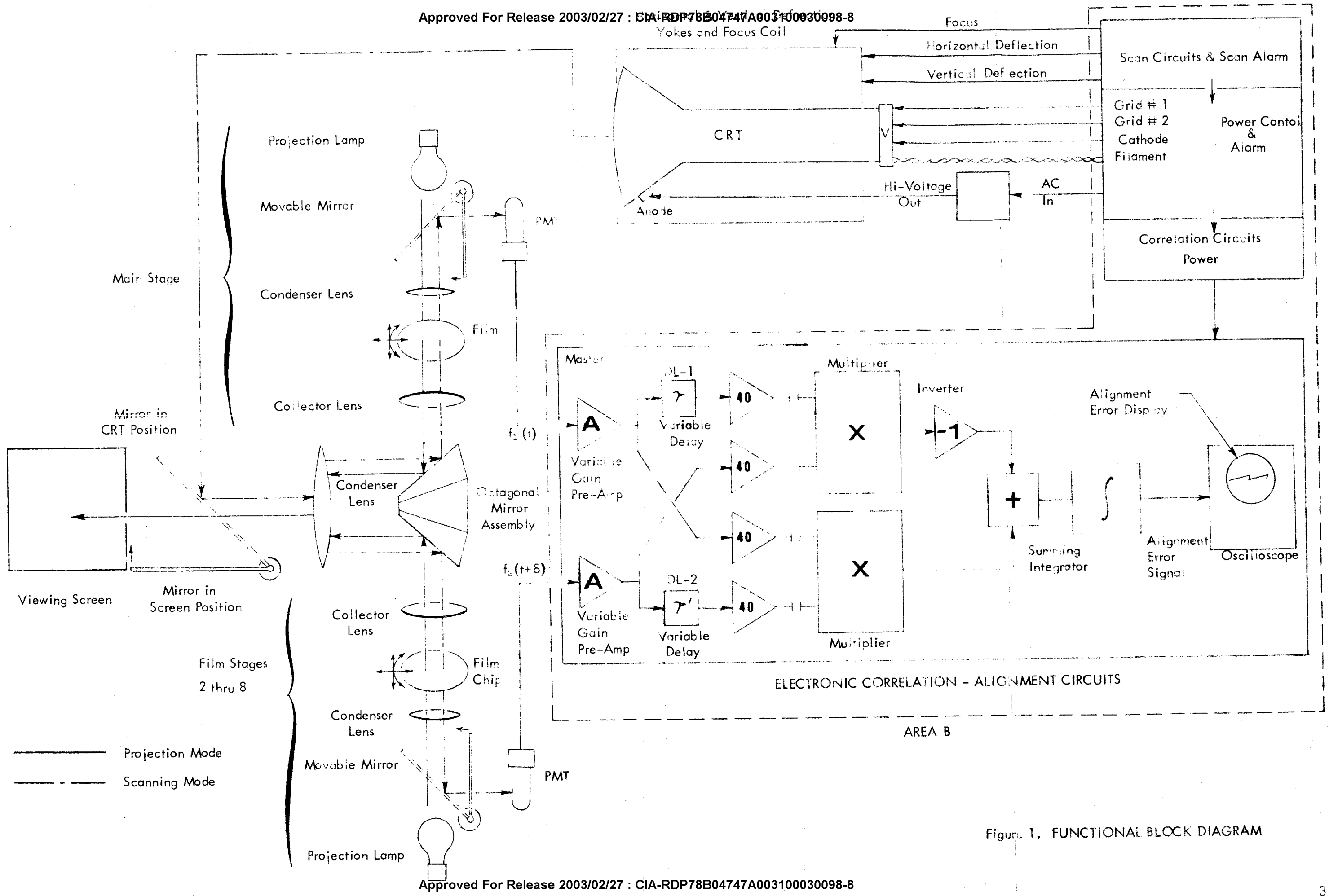


Figure 1. FUNCTIONAL BLOCK DIAGRAM

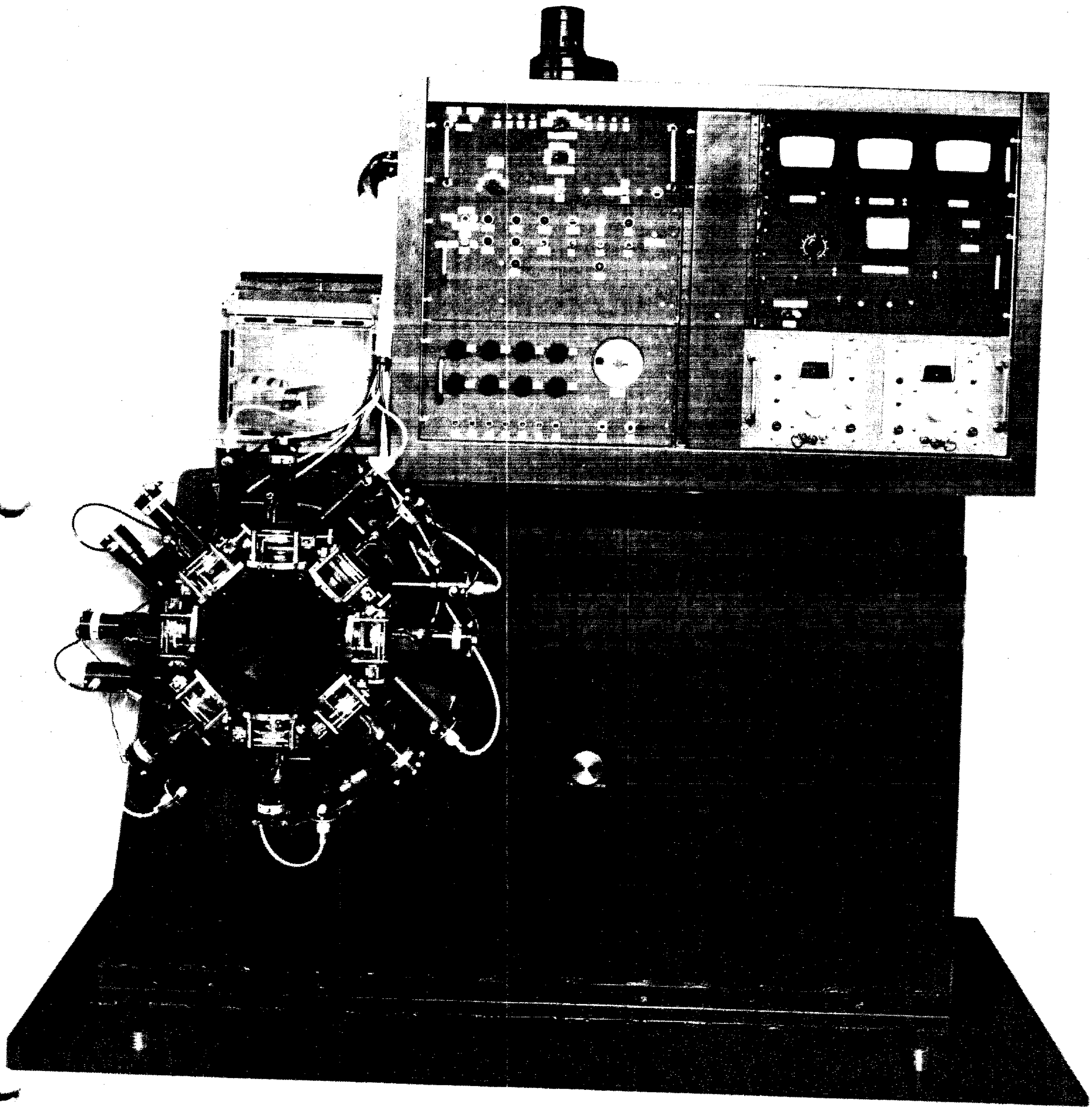

Figure 2. The Multiple Image Correlator

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## III. EQUIPMENT DESCRIPTION

The equipment consists essentially of eight film stages, an optical system, a scanning system, and a power control system. In the Projection Mode, the optical system projects the images to a viewing screen for visual alignment or for final composite photography. In the Scanning Mode, a scanning raster from a cathode ray tube is projected through the system to the film exhibits, where the information on the film is scanned and converted to electronic signals for electronic correlation.

### A. Film Stage Assemblies

Each film exhibit is a one-inch circular transparency mounted in a holder that screws into one of the film stages. The holders and stages are matched, and are color-coded to prevent interchanging. Each film stage is adjustable along two orthogonal axes, and each film transparency may be rotated through 360 degrees. Both coarse and fine controls are provided for all transparency adjustments. A microscope objective is mounted in the base of each film stage to serve as a collector lens during both the scanning and the projection modes. A housing (see Figure 3) containing a projection lamp, a photomultiplier tube, and associated optics is mounted on each one of the film stages. Figure 4 shows one of the film stages without the attached housing.

The film stages are mounted radially about an octagonal mirror assembly as shown in Figure 5. Stage Number One is the Main Stage. The film placed in this stage is used to produce a master image to which all of the other images are aligned.

### B. Optical System

The projection lamp behind each film stage assembly is located at the focal point of a lens so that the lamp projects a beam of collimated (parallel) light through the film. The resultant projected image is reflected via an assembly of eight 45-degree mirrors (one for each film stage) through and parallel to the optical axis of a large collimating lens (see component parts shown in Figure 6). The parallel light rays from

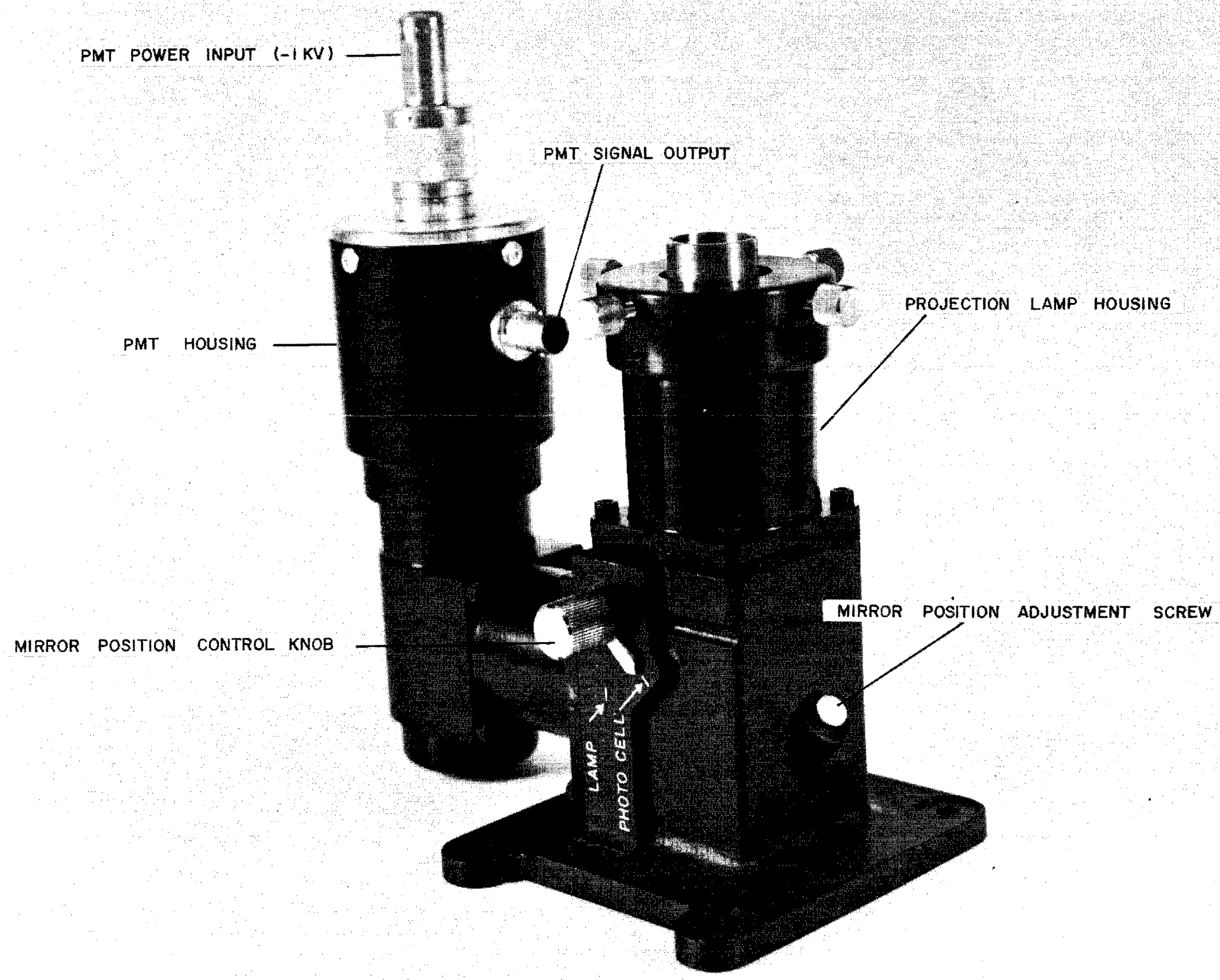


Figure 3. PMT and Projection Lamp Housing

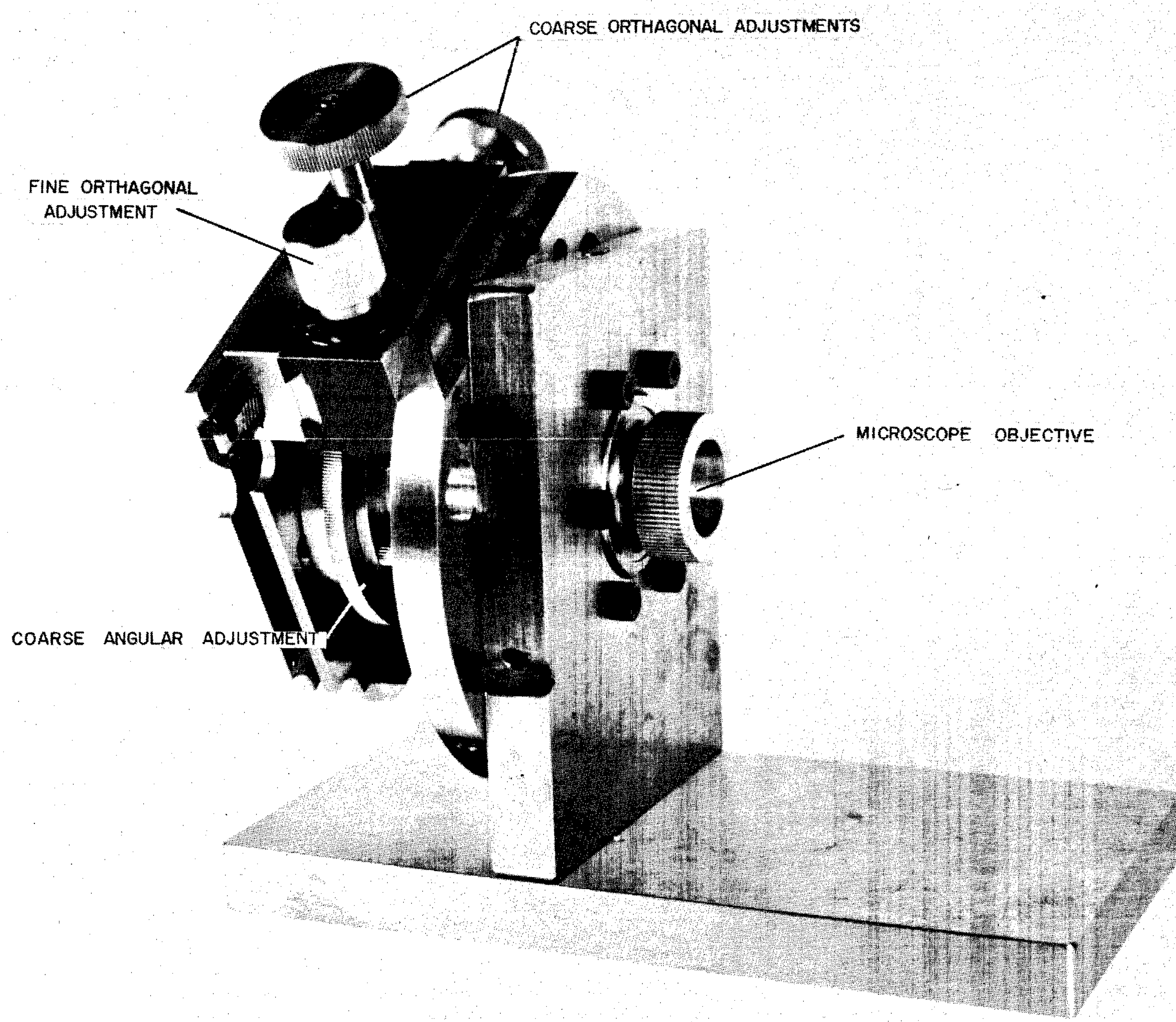


Figure 4. Film Stage

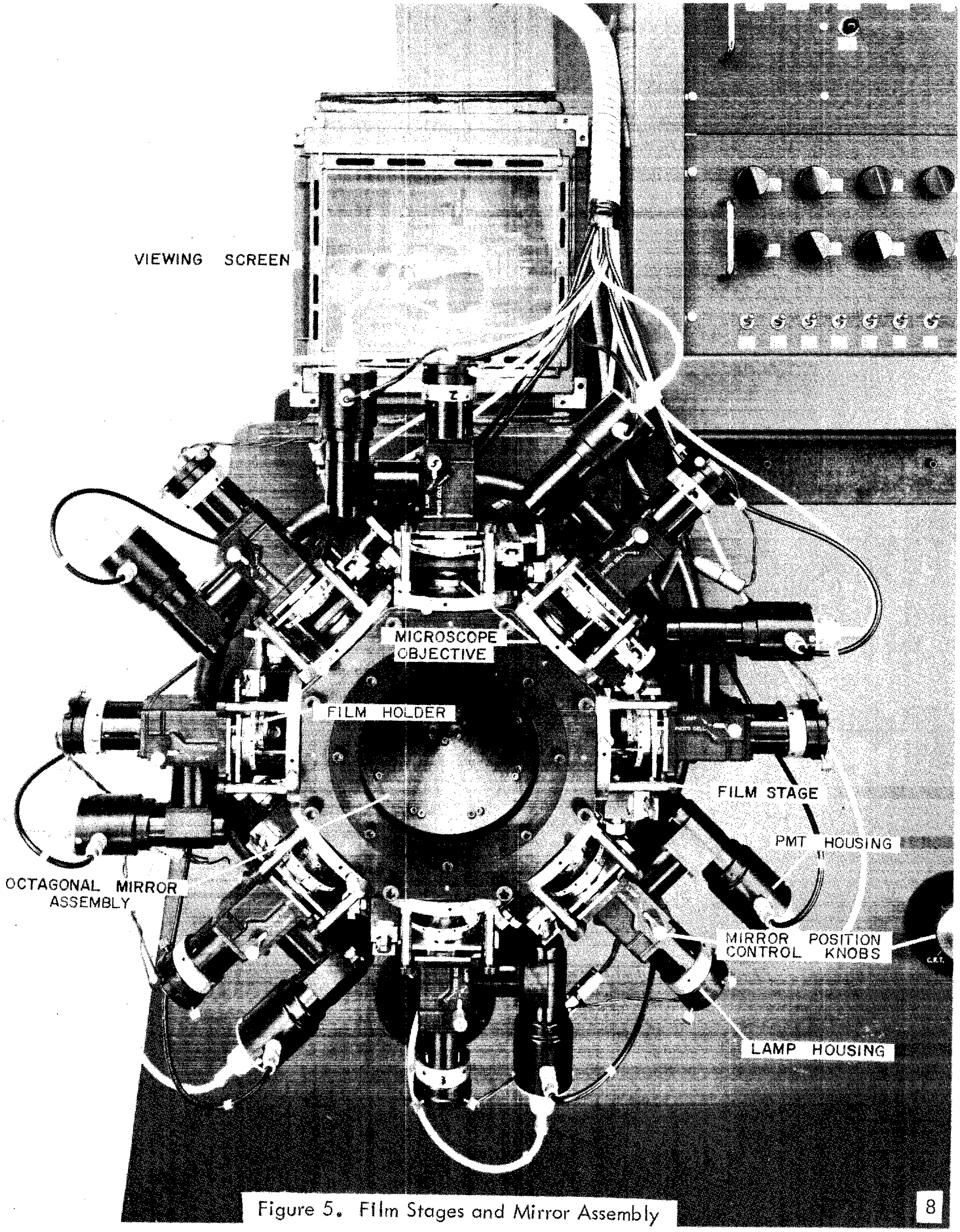


Figure 5. Film Stages and Mirror Assembly

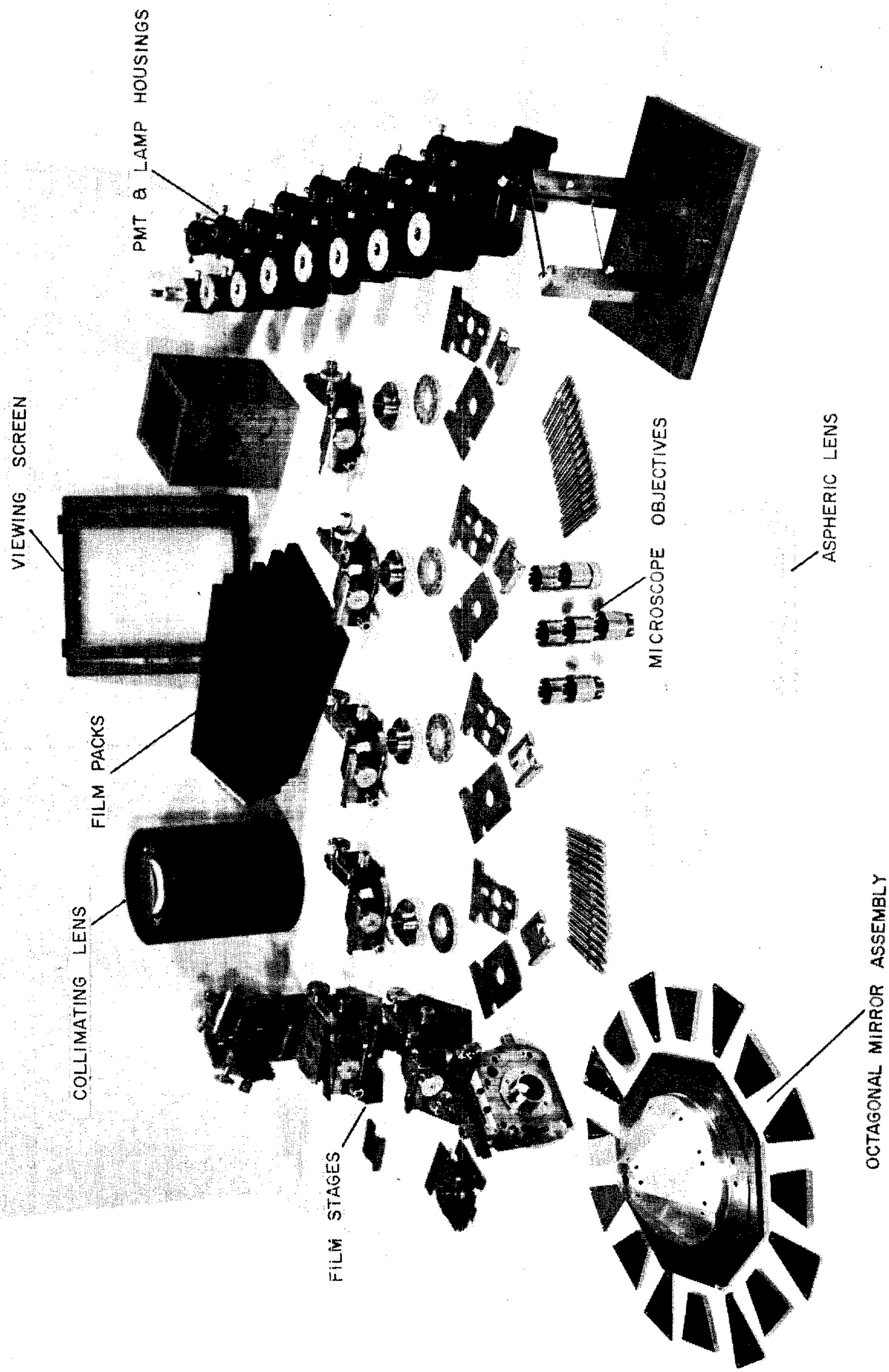


Figure 6. Component Parts



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each image converge at the focal point of this lens, where an 8x10-inch ground glass screen is placed to display the projected images. The result is that the projected images are superposed, and the image viewed on the viewing screen is a composite of all the images projected from the film stages.

Mirrors in the system accomplish the necessary optical folding. The positioning of one of the mirrors, a two-position plane mirror, is controlled by a knob on the front of the equipment. By changing the position of this mirror and by inserting additional mirrors into the optical system, the optical path can be diverted to a cathode ray tube at one end of the system, and to photomultiplier tubes at the other end of the system. This change in mirrors sets up the optical system for the Scanning Mode, which is used for electronic correlation and alignment (described in Section IV).

After electronic correlation and alignment, the mirrors can be returned to their original positions so that the images are projected again to the viewing screen. Then a film pack can be inserted at the viewing screen to take a composite photograph of all the projected images.

### C. Flying Spot Scanner System

This system consists of a CBS Electronics 7AVP24 cathode ray tube (CRT), eight photomultiplier tubes (PMT), and associated deflection yokes, focus coil, and scan circuits. The scan circuits generate a CRT raster pattern approximately one and one-half inches square. The spot size of this CRT scan is approximately one mil, and the pattern is repeated once every second.

In the Scanning Mode, the scanning raster is projected through the optical system to the film stages, where the microscope objectives reduce the raster size 25 times, and focus it on the film chips. This reduction process also reduces the spot size to approximately one micron, for close tolerance alignment. As the spot scans the film, the variations in the film density modulate the amount of light passing through the transparency. This modulated light beam is projected (via an inserted 45-degree mirror) onto the face of a PMT. The PMT transforms the modulated light beam into a modulated voltage (information signal). These signals are time sequence representations of the information scanned on the film chips. Electronic correlation techniques produce signals from this information that indicate magnitude, polarity and kind of misalignment between the main stage and any one of the other seven stages. These signals are displayed on an oscilloscope as alignment error signals.

### D. Control System

The Control System provides panels containing all the switches and controls necessary to the operation of the electronic portion of the equipment. (See Figure 7.) One of the controls provided adjusts out the attenuation differences in the delay lines. Besides generators, amplifiers, and control relays, the system also contains power control and alarm circuits. Their main function is to prevent damage to the CRT through component or circuit failures.

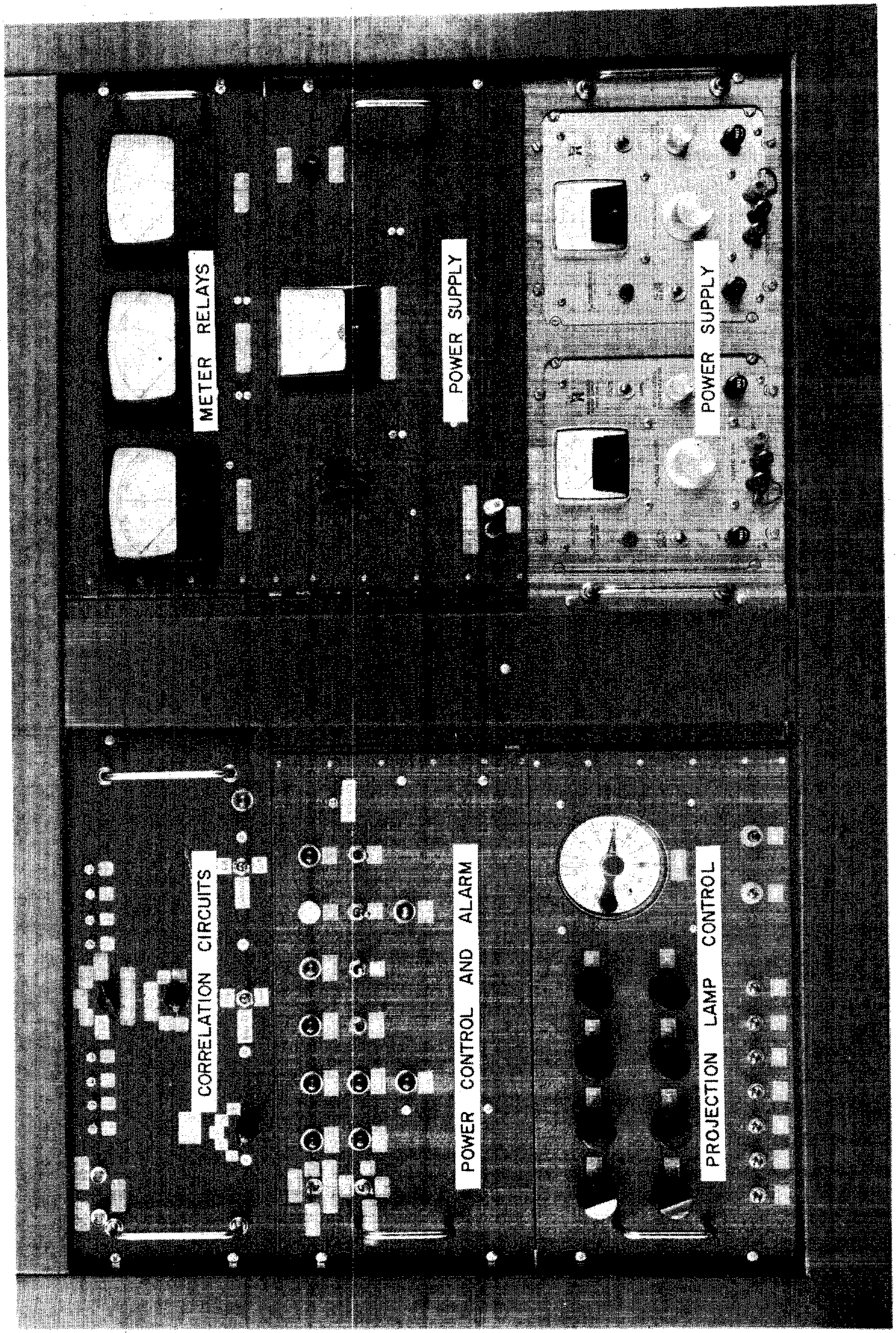


Figure 7. Control Panel



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## IV. GENERAL OPERATING PROCEDURES

Any number of transparencies up to eight may be correlated on the equipment, but in all cases one transparency is designated as the master to which all others must be aligned separately.

### A. Preparation

The film exhibits are prepared and inserted into the film stages. The master chip is always placed in the Main Stage while the others may be placed in any of the remaining stages. Light-tight rubber boots are placed around the film stages to shut out stray light. The operator sets the proper switches on the control panel to prepare and supply power to the equipment. This procedure lights the projection lamp in the Main Stage.

### B. Visual Alignment

For visual alignment, the operator must set the equipment to the Projection Mode. To do this he turns a mirror position knob on the Main Stage lamp housing to the LAMP position. This removes the 45-degree mirror from the light path. Then he moves the two-position plane mirror to the Projection Mode by turning the control knob to the SCREEN position. The equipment is then in the Projection Mode, and the transparency in the Main Stage is projected onto the viewing screen.

Using the controls on the Main Stage, the operator orients the master image to the desired location on the screen. Once this image is positioned, it is never changed during the alignment of subsequent images. Next, the operator turns on the lamp for the next film chip to be projected, and turns the mirror knob for that stage to the LAMP position. This image is then superimposed upon the master image at the viewing screen.

The operator brings the new image into alignment with the master by manipulating the film stage adjustment controls. One technique for aligning the images visually is to flicker the image by switching the projection lamp on and off while making adjustments in the position of the stage. The flicker technique gives an illusion of relative motion between unaligned images. The visual alignment would then consist of eliminating this relative motion.

Each of the remaining transparencies is superimposed in a like manner until all have been aligned to the master image.

### C. Electronic Correlation

The correlation circuits are allowed to warm up for a half hour with full power on. During this period, the operator plugs an oscilloscope into jacks provided on the control panel. After thermal stability has been achieved, the electronic analog multiplier is zeroed and calibrated, and a balance is obtained between channels. At this time, checks are also made on the other circuits to assure normal functioning.

For electronic alignment, the operator must set the equipment to the Scanning Mode. To do this he turns off the projection lamps, turns the mirror knobs on the lamp housings to the PHOTO CELL position (thereby inserting the 45-degree mirrors into the optical paths to reflect incoming light rays to the PMTs), and changes the two-position mirror to the CRT position. Then he sets the proper switches on the control panel to prepare the necessary circuits for the electronic alignment procedure. The scanning raster is projected onto the master transparency and onto one of the other transparencies selected for the first electronic correlation.

The first alignment is made with the delay lines set to the greatest delay (100 μsecs). The 100 μsecs delay serves as a coarse alignment detector, and eliminates the possibility of ambiguous error signals resulting from preliminary visual alignment.

The next step is to select a sweep speed for the CRT flying spot scanner. This speed is selected according to the bandwidth of the picture being scanned. Both the sweep speed and the number of steps (scan lines) are determined by the following relationships:

$$N_s = N_l \,, \quad N_l = \frac{T}{t/2} \,, \quad t/2 = l/\nu$$

where $N_s$ and $N_l$ are the number of steps and scan lines per raster or frame, T is time in seconds required to generate one complete frame or raster, $t/2$ is the time in seconds required to generate one complete scan line or the time between steps, $l$ is the length of scan at the film in cm, and $\nu$ is the sweep speed at the film in cm/sec. In this system T and $l$ are held constant at approximately 1 second and 0.15 cm, respectively. The sweep speed, $\nu$, and therefore $t/2$ and $N_l$, may be switched to one of two values shown below.

| $\nu$ | $t/2$ | N |
|---|---|---|
| 15 cm/sec | $10^{-2}$ sec | 100 lines/raster |
| 30 cm/sec | $5\times10^{-3}$ sec | 200 lines/raster |

The scanning rasters, now converted to PMT signals, are presented to the electronic correlation and alignment circuits where, once each second, these circuits electronically solve the equation

$$K/E \int_0^T f_1(t+\tau)\, f_2(t+\delta)\, dt \;-\; K'/E' \int_0^T f_1(t)\, f_2(t+\tau'+\delta)\, dt$$

where E and E' are the scale factors of the two multiplication channels; $\tau$ and $\tau'$ are the variable delays; and K and K' are the products of all the gains and attentuations in each of the two correlation circuit channels.

The solution to the equation is displayed on the oscilloscope as a periodic waveform, indicating both the sense and the magnitude of an alignment error. Typical electronic display errors are shown in Figure 8. The accuracy of the alignment error signal is limited by system tolerances; therefore, $\tau = \tau^{0}$, $E = E^{0}$, and $K = K^{0}$ must be approached as closely as possible. In addition, the error signal must be scaled to fall within a practical amplitude range. This range is determined not only by the practical limitations of the integrator, but also by the optimum signal input amplitude range of the electronic analog multiplier. Consequently, the preamplifier gains at the inputs of the correlation circuits are ganged to five discrete gain settings: 8, 16, 24, 32, and 40.

The operator observes the error signal displays, and accordingly adjusts the position of the film chip being aligned to the master. When the error signal on the oscilloscope is at a minimum, the operator rotates the scanning raster 90 degrees to check and correct the alignment on the other axis.

The alignment process is then repeated using first the 25 µsec delay lines, and finally the 10 µsec delay lines--each delay setting permitting a closer alignment of the projected images.

After the first transparency has been satisfactorily aligned with the master, the PMT is switched off and a second transparency is scanned and aligned in the same manner. This process is repeated until all the transparencies have been aligned with the master.

### D. Composite Photography

The system must be returned to the Projection Mode for photographing the composite image. The mirror knobs on the lamp housings are turned to the LAMP position, and the two-position mirror is placed in the SCREEN position. Then the operator sets the brightness level of each image to a common predetermined intensity (determined experimentally). He does this by measuring each image with a photographic light meter and adjusting lamp rheostats on the control panel. He then sets

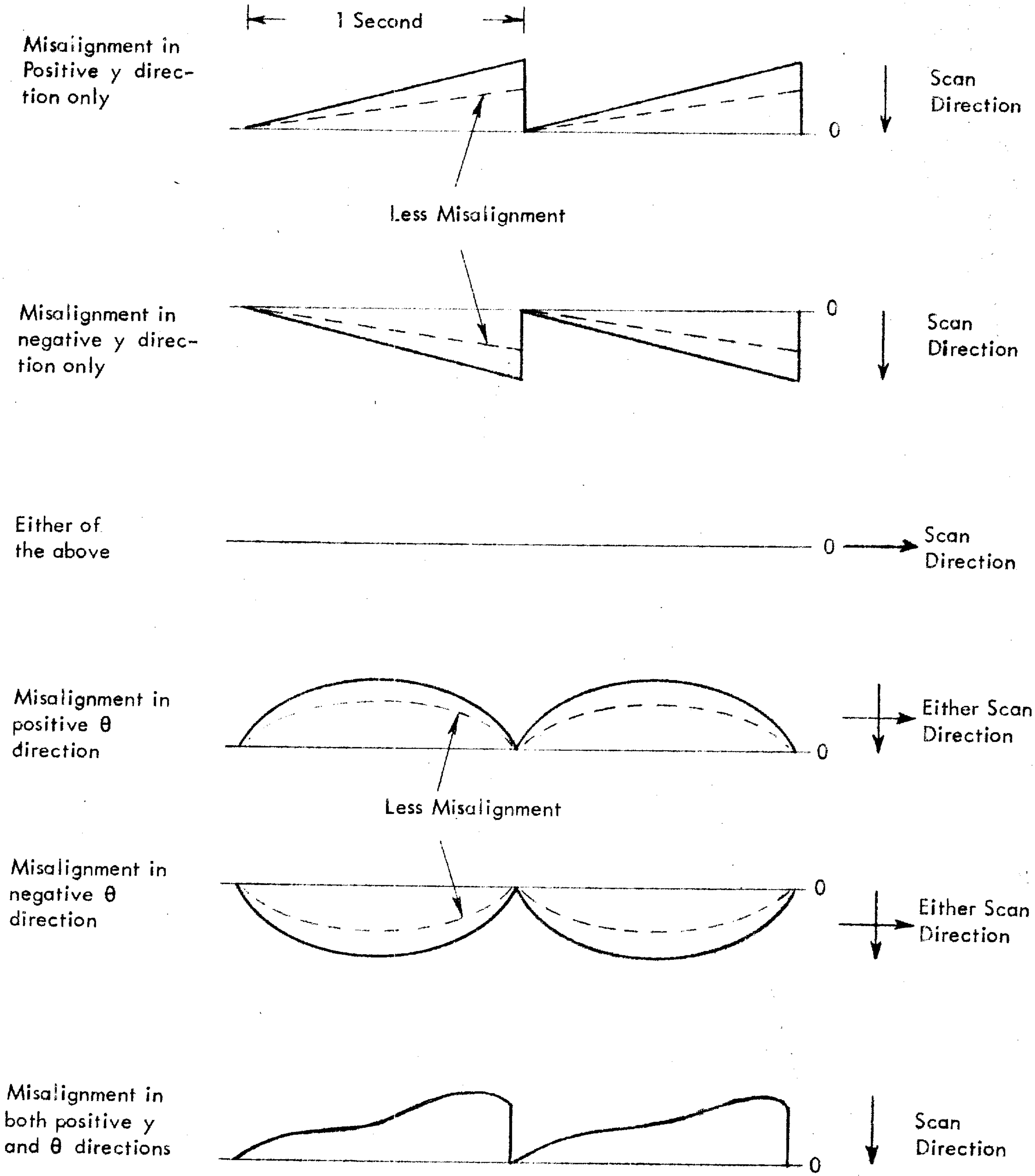


Figure 8

ELECTRONIC ALIGNMENT ERROR WAVE FORMS

the switches on the control panel so that all the necessary projection lamps are connected to a control timer. A film pack is inserted at the viewing screen and the timer is set for the proper exposure time (determined experimentally). When the exposure button is pressed, the projection lamps light simultaneously and project a composite image to the film plate. After exposure, the film plate is removed and developed in accordance with standard photographic laboratory techniques.

## V. RESULTS

The Multiple Image Correlator has achieved highly satisfactory results, as evidenced in a comparison of Figures 9, 10, and 11.* Figure 9 shows an enlargement of a single negative furnished [redacted] by the Customer. Figure 10 shows a composite photograph of three aligned images, and Figure 11 shows eight aligned images. There is no doubt that the information available has been greatly enhanced.

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The accuracy of electronic alignment techniques has not been fully developed due to component accuracy problems inherent in analog multiplier channels and delay lines. However, alternate courses of action and improved components are now available. The overall satisfactory performance of the equipment indicates that a small amount of additional engineering and the replacement of certain components will afford even better alignment capabilities. Also, intelligence gathered during the research and development of this equipment will be useful in designing and fabricating future equipments of similar nature, but with greater capacities and smaller dimensions.

*These figures were reproduced from positive transparencies produced by the equipment using standard blueprint techniques.

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## VI. SUMMARY AND RECOMMENDATIONS

The results furnished with this report prove that the Multiple Image Correlator not only is a valuable photographic exploitation tool, but also has great potential value in helping to establish camera design parameters and photo taking procedures. To achieve these ends, a two-fold approach is recommended.

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1. [redacted]hould retain the Multiple Image Correlator to perform a four and one-half month evaluation program. This program will be based upon the following tasks:

   a. Develop techniques for accommodating photo samples taken under varying conditions by various cameras (e.g., photos having the same basic geometry and scale, but differing perhaps in lighting).

   b. Maximize the effectiveness of the electronic system.

   c. Establish operating procedures for the equipment.

   d. Synthesize from this program design specifications for more sophisticated equipment in accordance with Customer guidance concerning operational and technical requirements.

2. Concurrently with the above program, the development of a Multiple Image Correlator with greater input flexibility should be initiated.